



## GEOGRAPHY | RESEARCH ARTICLE

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\*Corresponding author: Grete K. Hovelsrud, Nordland Research Institute, Bodø, Norway; Faculty of Social Sciences, Nord University, Bodø, Norway  
E-mail: [grete.hovelsrud@nord.no](mailto:grete.hovelsrud@nord.no)

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Ben Derudder, Universiteit Gent,  
Belgium

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## GEOGRAPHY | RESEARCH ARTICLE

# Prepared and flexible: Local adaptation strategies for avalanche risk

Grete K. Hovelsrud<sup>1,2\*</sup>, Marianne Karlsson<sup>1</sup> and Julia Olsen<sup>1</sup>

**Abstract:** Living with avalanche risk and road closures is part of everyday life for many communities in avalanche prone areas. This paper illustrates the interplay and dynamics of adaptive capacity and social capital through locally developed adaptation strategies to avalanche risk in two case areas in Northern Norway. Social capital includes empirically derived categories that are often connected to adaptation research: social networks and trust, place attachment, local and experiential knowledge, engaged individuals and perception of risk. These play a significant role in activating adaptive capacity, which results in adaptation strategies. The paper illustrates how adaptive capacity and resulting adaptation are outcomes of interacting, rather than individual, attributes of social capital. The adaptation strategies align in three broad categories: preparedness, flexible arrangements and influencing decision-makers. The paper shows that the communities demonstrate high adaptive capacity to deal with risk and that social capital plays a role in ensuring and shaping such capacity. However, there are significant costs associated with adaptation strategies aimed at sustaining the functions of everyday life and critical services. Such costs are relatively similar in the case areas and include limited mobility and participation in social activities, economic losses and the potential for failure to deliver health services, but they manifest in different degrees in each case study. The paper underlines the importance of the local context, which is critical for understanding

### ABOUT THE AUTHORS

Grete K. Hovelsrud is an arctic anthropologist focusing on interdisciplinary studies of adaptation to changing climatic and societal conditions, adaptive capacity of coupled social-ecological systems, and on the transformation to a low-emission society in the context of climatic and societal change. She has extensive fieldwork experience from communities, primary sectors, such as fisheries, agriculture, reindeer herding, aquaculture, and municipalities in the sub-Arctic and the Arctic. The findings and theoretical elucidations presented here align well with hers and her team's emphasis on perceptions of risk, cultural theory of risk, co-production of knowledge and adaptive co-management. The emphasis on the local context is a critical starting point for understanding impacts, risks, adaptation, adaptive capacity, and change. While this research is critical for understanding the particularities of the local context, the processes and insights are highly relevant for other local communities and for national and international policy for governing risk.

### PUBLIC INTEREST STATEMENT

For many natural-hazard prone communities worldwide, daily life comes with a profound amount of uncertainty and risk. This study highlights certain social dynamics within Northern Norwegian communities that allow them to adapt to avalanche risk, which, like other natural disasters, is further exacerbated by climate change. It was found that a community's ability to adapt relies on the interaction of these social dynamics, including local trust, social networks, local knowledge, engaged community members, and overall perception of risk. Yet, where adaptation is possible, strategies, such as preparedness, being flexible and contact with policy makers are often hampered by the high cost of sustaining everyday life in spite of avalanches. Thus, while certain natural hazard risks might be similar for exposed communities worldwide, these communities vary in their ability to respond, making the local context critical for understanding both the consequences of natural hazards and the socio-political settings that enable adaptation.

both the impacts of natural hazards, such as avalanche and the socio-political contexts, which may either enable or hinder activation of adaptive capacity and adaptation strategies.

**Subjects: Environmental Studies & Management; Climate Change; Environmental Issues; Social Sciences; Risk; Hazards & Disasters**

**Keywords: local communities; avalanche risk; Northern Norway; Arctic; adaptive capacity; social capital; adaptation strategies; climate change; multiple stressors**

## 1. Introduction

To drive in the winter darkness on snow covered roads, fringed by mountain slopes where avalanches are known to occur, is a part of everyday life for many living in avalanche prone areas. In addition to presenting risks to human health and life, avalanches cause road closures as a result of either an actual avalanche or a safety measure in anticipation of an event (Frauenfelder et al., 2013; Jacobsen, Leiren, & Saarinen, 2016; Kristensen, Kristensen, & Harbitz, 2003). Road closures limit the mobility of people, goods and services for a few hours or for several days. Depending on the surrounding infrastructure, communities can become isolated or people can be forced to take long detours. Avalanche risk and infrastructure disruption have consequences for individuals, local communities, economic sectors. This is exemplified in northern Norway where, industries such as fisheries depend on reliable and rapid transport of perishable products, and the tourism industry (Hovelsrud, West, & Dannevig, 2015). Avalanches are prevalent in Norway and, to date, the research focus has primarily been on geophysical conditions and technical means of risk reduction (Norges Geotekniske Institutt NGI, 2013). Avalanche risks are closely associated with topography and extreme weather conditions (Bjørndal & Helle, 2011; Hanssen-Bauer et al., 2015; Jaedicke et al., 2008). Changes in climate variables such as wind, the amount and type of snow, and temperature will alter the intensity, frequency and timing of avalanches (Frauenfelder et al., 2013). In Northern Norway, near-zero temperature events, combined with moderate to high intensity rainfall, increased amount of snow in mountain areas, and wind are identified as critical triggers of avalanches (Frauenfelder et al., 2013; Hanssen-Bauer et al., 2015; Norwegian Road Administration, 2015). In response to increased vulnerability, the Road Administration has recently evaluated the exposure to avalanches in Northern Norway and suggests the implementation of protective measures, while also noting that climate change and variability may challenge the efficiency of such measures (Norwegian Road Administration, 2015).

While changing climate and weather conditions impact the magnitude and location of avalanche risk and generally challenge transportation and infrastructure, increasing safety standards over the past decades have led to more frequent road closures. That is, roads are more likely to be closed due to avalanche risk as a precautionary measure rather than closing after an actual avalanche has occurred.

Research from other avalanche-prone regions, such as the alpine regions of France and Austria, highlight discrepancies between the true risk of natural disasters, including earthquakes (Beck, André-Poyaud, Davoine, Chardonnel, & Lutoff, 2012) and avalanches (Leiter & Pruckner, 2005), and individuals' perceptions of their personal risk exposure. Other studies from the Alps show that natural hazard risks of outdoor activities, such as winter sports, are perceived as "acts of God," and thus uncontrollable (Eitzinger & Wiedemann, 2006). Additional conducted in the Canadian backcountry, focuses primarily on avalanche geomorphology and forecasting (Stethem et al., 2003). Some studies address the response and preparedness towards avalanches, but report only on quantitative results, rather than on community risk perception and response to avalanches (Haegeli & Haider, 2012). Others recognize the need for local health and safety regulators to understand how individuals relate and respond to risk (Slovic, 1987), but the effectiveness of this strategy has yet to be studied in a salient way. Although, Haegeli et al.'s research on backcountry snowmobilers in Canada report linear relationships between avalanche danger ratings and adjusted snowmobiling behaviour, little data is presented on how these snowmobilers are making their decisions and how they perceive

avalanche risk on an individual and personal scale. The study, however, alludes to the importance of social capital (largely in the form of experiential knowledge and social networks). The same is true for individuals living in flood-prone areas, where strengthening local support networks and improving residential knowledge about flood risk fostered natural disaster preparedness (Scolobig, De Marchi, & Borga, 2012). Studies of avalanche danger in residential areas emphasize mapping and zoning or construction of retarding structures to mitigate avalanche fatality (Jamieson & Stethem, 2002) but do not elucidate how societal perceptions and behaviors influence the preparation and understanding of the initial avalanche risk. Yet other studies find that those who are affected at local levels, such as caregivers and health providers, perceive that the problems posed by extreme weather events are severely underestimated aspects of home and community life (Skinner, Yantzi, & Rosenberg, 2009). These studies, however, lack a clear focus on how avalanche risks are experienced by the people and communities who are, in fact, exposed to such risks. Previous research (Leiter, 2011) has noted that the relevance of perceived risk changes when focus is shifted from perception of average risk to perception of personal risk, thus making the individual perspective an imperative part of accurate risk assessment. While some recent studies (e.g. March, Kornakova, & Leon, 2017) have documented forms of short and long-term responses at multiple stages of disaster, these have not investigated the societal aspects that build adaptive capacity. This paper addresses critical research gaps by exploring how two communities in Troms County, Northern Norway, which yearly experience avalanches and road closures, perceive, respond to and handle avalanche risk and infrastructure disruption, and what such risks mean for affected peoples' lives and livelihoods. In light of on-going and projected climate change and the safety and connectivity demands associated with contemporary life, it is important to develop an understanding of how local communities can adapt to and live well with avalanche risk. We combine the concepts of adaptive capacity and social capital to analyze how the studied communities in Northern Norway experience and respond to infrastructure disruption and avalanche risks.

An increasing body of literature emphasizes the role of bottom-up strategies and local knowledge as a necessary complement to more formalized modes of disaster preparedness, adaptive capacity and climate change adaptation (e.g. O'Brien, Eriksen, Nygaard, & Schjolden, 2007; Smit, Hovelsrud, Wandel, & Andrachuk, 2010; van Aalst, Cannon, & Burton, 2008). Research also shows that social processes including norms, relationships and values, shape both responses and outcomes of risk (e.g. O'Brien & Wolf, 2010) and that adaptation is an interactive social process (e.g. Hovelsrud & Amundsen, 2017). Inspired by such research approaches, our objectives are to (1) examine how identified aspects of social capital shape adaptive capacity as manifested in particular adaptive strategies and (2) analyze societal outcomes of living with and adapting to avalanche risk in two communities.

## 2. Conceptualizing adaptive capacity, social capital and adaptation

We draw on the concepts of adaptive capacity and social capital to analyze how the studied communities in Northern Norway experience, respond and adapt to infrastructure disruption and avalanche risks. Adaptive capacity is a key concept in the global environmental change literature (e.g. Armitage & Plummer, 2010; Engle, 2011; Smit & Wandel, 2006) and refers to the ability of a sector, community, or household, to cope with, adjust to, or recover from an exposure to, for example, extreme weather (Smit et al., 2010; Smit & Wandel, 2006).

Adaptive capacity is closely related to the concept of adaptation, here understood as the translation of adaptive capacity into actions and strategies in response to events and change processes (e.g. Hovelsrud & Smit, 2010; O'Brien et al., 2004). The outcomes of adaptive actions and strategies vary from maintaining existing societal functions to effectuating change which can be incremental or transformational (Pelling, 2010). Adaptive capacity shapes the range of options and actions available and can enable or restrict the ability to deal with future change (Pelling, 2010). Adaptive capacity is context-specific and shaped by *inter alia* rights and access to resources, equity, infrastructure, scientific and traditional knowledge, enabling institutions, governance, and the distribution of benefits and costs (Adger, Dessai, & Goulden, 2009; Brown & Westaway, 2011; Hovelsrud & Smit, 2010;

Keskitalo, Dannevig, Hovelsrud, West, & Swartling, 2011; Kofinas, Clark, & Hovelsrud, 2013). Adaptive capacity can be latent, and activated through human agency (e.g. Bay-Larsen & Hovelsrud, 2017; Brown & Westaway, 2011, p. 322) and is nested in cross-scale societal processes that may hinder or enable action (e.g. Hovelsrud & Amundsen, 2017).

Adaptive capacity and its operationalization are mainly social processes characterized by social norms and values (Adger et al., 2009; Ostrom, 1998, 2011). Social processes and relationships in turn create social capital (Bihari & Ryan, 2012), social commonly defined as: “the ability of actors to secure benefits by virtue of membership in social networks or other social structures” (Portes, 1998, p. 6). Through such social processes and networks people are enabled to achieve what they are unable to do on their own, such as engaging in collective action (Adger, Huq, Brown, Conway, & Hulme, 2003). Deployment of social capital leading to collective action has been found to substitute adaptive measures that typically fall within the responsibility of the state (Adger et al., 2003; Agrawal & Perrin, 2009). The ability of a group to act collectively to address problems (Coleman, 1988; Putnam, 2000), trust relations, share experiences and knowledge, combined with ongoing social relations that build social cohesion (Duhaime, Searles, Usher, Myers, & Fr chet te, 2004), shapes how adaptation can proceed.

Inspired by Pelling and High (2005), we argue that social capital plays a significant role in adaptive capacity and in how a group can prepare for and adapt to infrastructure disruption and avalanche risk. In combining the literature on social capital and adaptation with empirically derived findings we have identified six interrelated key aspects that play a significant role in shaping adaptive capacity: social networks and trust, place attachment, local and experiential knowledge, engaged individuals and perception of risk. Our analysis of how these key aspects interact closes the current knowledge gap of how adaptive capacity is generated and turned into local adaptation strategies to deal with avalanche risk in the two case communities in Northern Norway.

Social networks reveal, embody, and provide access to social capital (Dowd, Marshall, Fleming, Gaillard, & Howden, 2014; Hahn, Schultz, Folke, & Olsson, 2008; Kofinas et al., 2013; Putnam, 2000) and such capital includes individual positions and ability to co-operate (Putnam, 2000). Conversely, loss of social capital may weaken network connections, trust and skills (Dowd et al., 2014). Social networks (formal and informal) mirror social relationships and the motivations for both connections and detachments (Akama, Chaplin, & Fairbrother, 2014; Bodin & Crona, 2009). Repeated interactions within a community through different forms of social networks generate reciprocity and trust. Akin to social networks, trust and reciprocity are highly context-specific, and therefore manifest differently according to context (Akama et al., 2014). Trusting relationships within communities and toward external actors are important to enable responses to emergencies as well as to plan for future strategies (Kapucu, 2008). As a component of social capital, trust shapes preparedness and responses to natural hazards such as avalanches and risk perceptions (L fstedt, 2005).

Attachment to place is another dimension of both social capital and adaptive capacity, and a powerful motivator for adapting to change (Adger et al., 2009; Amundsen, 2013; Fresque-Baxter & Armitage, 2012). Place attachment is commonly expressed through the identity, and sense of pride of belonging created around a settlement or place (Low & Altman, 1992). It thereby contributes to the quality of life and well-being of individuals in a community and has been found to influence connections between different social groups within a place (Adger, Barnett, Brown, Marshall, & O’Brien, 2013). Place attachment can be a driving force in addressing community concerns and enabling preparedness and adaptive actions (Akama et al., 2014; Bihari & Ryan, 2012), and governance processes to deal with risk such as floods, are found to be inadequate when place attachment is strong (Clarke, Murphy, & Lorenzoni, 2018). Social capital and place attachment are closely linked in a feedback loop: high social capital may lead to robust places, leading to stronger place attachment, which in turn strengthens social capital (Akama et al., 2014).

Local and experiential knowledge play an important role in enabling communities to deal with environmental and climatic change because such knowledge forms are inherently tailored to specific places and situations (Colfer, 2005; Olsson, Folke, & Berkes, 2004). Local knowledge can contribute to social learning and “appropriate” responses to natural hazard events (Prior & Eriksen, 2013). Perry, Lindell, and Tierney (2001) suggest that there is a direct correlation between preparedness and level of experience; more exposure equals better preparedness. Conversely, previous experience may also have a negative effect on local preparedness by making people more acclimated and potentially decreasing their level of preparedness by virtue of being able to conceptualize the threat (Bihari & Ryan, 2012). Sharing of knowledge is important for dynamic communities where newcomers need to learn about uncertain threats, the role of social networks is therefore closely linked to such sharing (Prior & Eriksen, 2013).

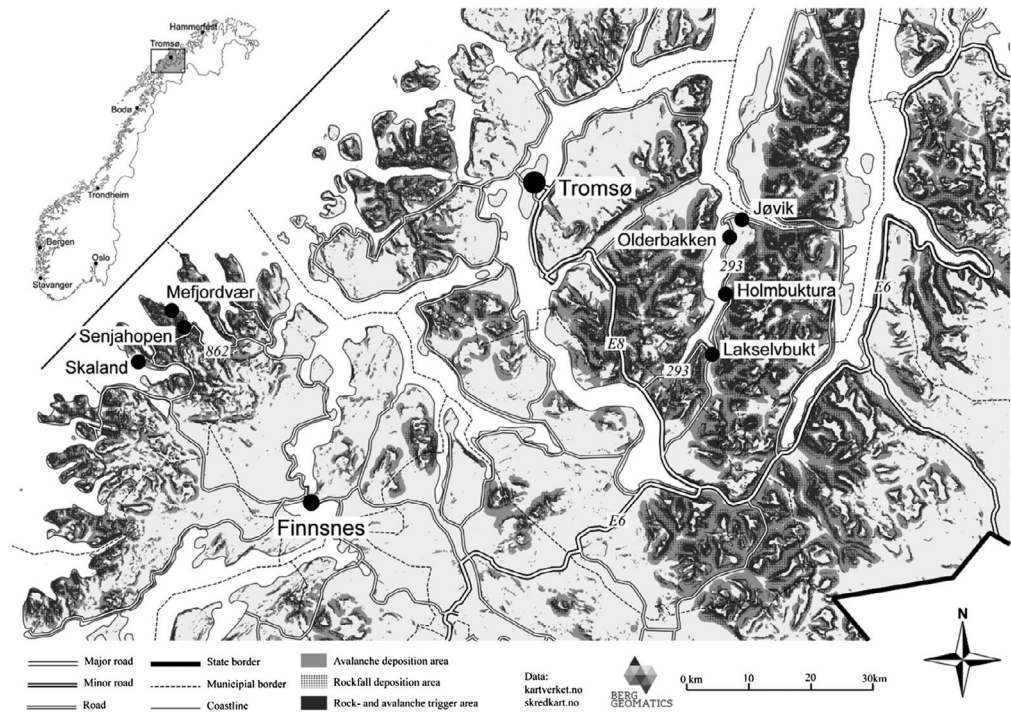
Engaged individuals have the ability to bring attention to challenges and risks in their community, such as the need for climate adaptation or avalanche protection, and thereby directly influence a policy agenda and/or decision-makers (Dannevig, Hovelsrud, & Husabø, 2013). Engaged individuals are important for contending with focusing events such as a severe avalanche, that capture public and policy makers’ attentions and thereby possibly increase the rate of policy measures (Birkland, 1997; Penning-Rowsell, Johnson, & Tunstall, 2006). In climate adaptation, engaged actors typically recognize a problem and start a process of developing proactive measures by bringing the issue to the attention of policy makers (Baumgartner & Jones, 1993). This illustrates that human agency is critical for developing adaptation strategies (Dannevig et al., 2013). The motives for such “adaptive agency” (Pelling, 2011) are closely related to values, world views (O’Brien & Wolf, 2010) and place attachment, and may be enabled or constrained by institutional factors (Hovelsrud & Amundsen, 2017).

Perception of risk, or how individuals perceive and react to the potential for natural disasters such as avalanches, floods, and debris flows, is an integral part of comprehensive risk assessment, as knowledge gaps surrounding such risks can pose threats to overall safety (Fuchs et al., 2017). At the community level, perception of risk depends heavily on social, cultural, and economic factors (Jóhannesdóttir & Gísladóttir, 2010), but individuals also play active roles in informing and preparing themselves for natural disasters (Wagner, 2007), thus necessitating an abundance of social capital effective network capacities for vulnerable areas (Działek, Biernacki, & Bokwa, 2013). It is increasingly recognized that people perceive risks, such as that of climate change, from the perspective of world views, values, beliefs, and livelihoods and the internalization of high variability in weather and resources such as in fisheries (Dannevig & Hovelsrud, 2016; Jasanoff, 2010; O’Brien & Wolf, 2010). The way people perceive risk in Northern Norway is often reflected in narratives about high resilience and adaptive capacity to highly variable and unpredictable conditions (Amundsen, 2012; Bay-Larsen & Hovelsrud, 2017; Hovelsrud et al., 2015), shaping adaptation and adaptive capacity (Dannevig, Bay-Larsen, van Oort, Keskitalo, & Keskitalo, 2015). In addition, knowledge, experience, social networks and life opportunities shape how people interpret, perceive, and act upon knowledge of risks, both positively and negatively (Babcicky & Seebauer, 2017; Crate, 2008; Heyd, 2008). Thus, different aspects of social capital, singularly or combined, influence and shape how people perceive risk and opportunity. Because perception of risk is here seen as an outcome of the interaction between the different aspects of social capital, it is included as a part of the social capital ensemble. By breaking down the concept of social capital into particular and interacting dimensions, we are able to elucidate the motivation for living with risk, and how the selected social capital dimensions have a bearing on both adaptive capacity and adaptation.

### 3. Setting the stage: Research context and approach

This paper focuses on avalanche risk and road closure in two case areas, Senjahopen and Holmbuktura, both located in Troms County, Northern Norway (Figure 1 and Table 1). Troms County is one of the least populated regions in Europe. It is characterized by steep and rugged mountains with long distances between settlements. Due to the area’s topography and settlement patterns, several communities are exposed to avalanche risk and sudden road closure (Jacobsen et al., 2016).

**Figure 1. Map showing the case areas and avalanche proneness.**



**Table 1. Summary of research methods and interviews**

Methods	Senjahopen	Holmbuktura	Tromsø
Individual semi-structured and open-ended interviews	11	14	1
Group interviews	7	0	1
Scoping interviews conducted at town meeting			1

When avalanche risk is imminent, exposed road sections are closed by the regional authorities and the Norwegian Road Administration as a safety measure. The avalanche season typically starts ultimo November and ends late in May (Bjørndal & Helle, 2011, p. 12) and overlaps with the cod fishing season (Lyngstad, 2015). The lack of daylight makes it difficult to observe changes in the mountain slope and can therefore exacerbate avalanche risk.

Information about natural hazards and avalanche risks is available on the webpage “varsom.no”, provided by the Norwegian Water Resource and Energy Directorate (NVE), the Norwegian Meteorological Institute (met.no), the Norwegian Road Administration and the Norwegian National Rail Administration. Varsom.no provides information about exposed terrains and avalanche danger levels from December through May (Varsom. no, 2016). NVE also employs a couple of residents in avalanche-prone communities in both areas to report on the current weather, snow and avalanche conditions to ensure updated information.

### 3.1. Case area descriptions

The two case areas encompass several settlements, which provides a richer context and allows for comparison within the case areas as well as between them. The Senjahopen and Holmbuktura areas were selected because they exhibit interesting similarities, including remoteness and geography, and notable contrasting features, such as size, economic activity, alternative roads and character of risks. Until recently, the coastal communities in Troms County were only accessible via boats and ferries, which makes avalanche risk and road closure relatively recent challenges.

### 3.1.1. *The Senjahopen area*

The Senjahopen area, in Berg municipality, comprises the settlements of Senjahopen, Mefjordvær, and Skalands, located on Senja, the second largest island in Norway (Figure 1). There is seafood industry, a school, a kindergarten, a food store, a local bank and paramedic services in Senjahopen. Mefjordvær has a hotel, while Skalands is the municipal center with a graphite mine, a nursing home and other administrative services.

The area has around 650–700 inhabitants, and has experienced both outmigration, and immigration of refugees and seasonal laborers. The proximity to rich fishing grounds and a relatively sheltered harbor has made fisheries the backbone of the local economy. One of the largest fishing harbors in Troms County is located in Senjahopen, and until recently fish products used to be shipped by boat (Berg Næringsforum, 2008, p. 4). However, there has been a steady increase in the exportation of fish products by heavy trucks, and the frequency of road transport and heavy trucks is likely to increase as the fisheries and seafood sectors are expected to grow (Lyngstad, 2015, p. 31). In addition to fisheries, tourism is rapidly increasing with a focus on outdoor activities such as hiking, skiing, whale watching and northern light watching.

The County Road 862 connects Senjahopen to other settlements on Senja and to the city of Tromsø, the county capital. The road to Senjahopen was opened in 1978 and extended to Skalands in 2004. It passes through a section called Svartholla, which is prone to avalanches and land and rockslides. Avalanche protection has been built along Route 862, but if avalanches occur outside these areas, the road is often closed. Moreover, the steepness of the newer road section is challenging for heavy trucks, in effect reducing the number of heavy vehicles. Route 862 is important for local industries and tourism; eighty percent of the road system in the Berg municipality belongs to the national tourist road system. Any closure of the available routes leaves travelers with a detour option between settlements of approximately 100 km. When both road sections to Senjahopen are closed, the settlement is only accessible by boat. The limitations in mobility due to infrastructure disruption have consequences for residents, visitors and local industries, though there is an ambulance and a rescue boat based in Senjahopen, which provides a sense of security should an emergency occur. Road closure also has implications for the local economy, particularly the fishing industry, which depends on reliable transportation. Fresh fish has a greater market value than processed fish and a road closure could entail the loss of fresh products.

In addition to varsom.no, information about avalanche conditions is published on the Berg municipality and The Norwegian Public Road Administration web pages, in the media and on social media. In 2013, after fatal avalanches in the region, the Berg municipality applied a new warning method by sending an SMS-alert to all residents with information about road closure/opening, public transport schedule, and sources for further information. Information about road closure and conditions is also available on an information board placed near the bridge from Finnsnes.

### 3.1.2. *The Holmbuktura area*

The Holmbuktura area in Tromsø municipality consists of three small settlements with a population of approximately 218. The area's primary school, church, supermarket and nursing home are located in Lakselvbukt, the largest settlement with 125 inhabitants. From Lakselvbukt, the seashore dead-end County Road 293 passes through Holmbuktura (the avalanche area) before reaching the settlements Olderbakken and Jøvik. Olderbakken and Jøvik, with a combined population of 93 residents, were historically more populous with a large fish oil factory, fish landing facilities, a post-office, a small shop and a school. The fish factory closed down in 1996 and the school in 2010, and with them employment opportunities. There are currently few jobs in Olderbakken and Jøvik. The result is that the outer side of Holmbuktura experiences outmigration and the remaining population ages.

Before the road was built in the 1970s, ferries and boats connecting coastal communities were the primary means of transport. The Holmbuktura area is an hour's drive from Tromsø center, where many people commute for work. There are no alternative roads to the outer side of Holmbuktura and



avalanches or risk of avalanches typically close the road every winter. These closures can last several days and thereby isolate Jøvik and Olderbakken (Jacobsen et al., 2016). Due to the characteristics of the mountain slopes and to the close proximity to the sea, travelers face a potentially fatal risk by driving through the avalanche-prone road sections. Avalanches typically originate from the mountain snowdrifts more than 1000 meters above the road. Post-avalanche snow depths range from 2–20 meters (Jacobsen et al., 2016). Road closures limit mobility and accessibility for residents living on the outer side of Holmbuktura, but they also affect the larger community.

Information about road closures and avalanche risk is accessed through varsom.no, on social media or by calling the snow removal company in charge of deploying road barriers. The Norwegian Road Administration is currently evaluating alternatives for a new road with a bridge connecting Ullsfjord with Lyngen. Jøvik is enlisted as a possible alternative and can, if realized, shorten the commute to Tromsø. This road connection will not be operational until 2050 (Norwegian Road Administration, 2016). During winter 2017, the Road Administration has been testing radar as a new avalanche monitoring method. The radar use has led to fewer road closures compared to previous seasons (Norwegian Road Administration, 2017). Our data collection was carried out before the deployment of the radar equipment.

### **3.2. Methods and data collection**

In this explorative study, we have utilized a set of mixed qualitative methods (Blaikie, 2010) to understand how different dimensions of social capital shape adaptive capacity and result in adaptation strategies to avalanche risks. Methods used include media-review, literature review, scoping interviews, semi-structured interviews and participant observations in the communities (Table 1).

A media-review (1986–2015) provided background information on the occurrences, media attention, and local concerns relating to avalanches and road closures, and helped identify local actors in both areas. The search through an electronic archive of Norwegian written and radio news (*A-tekst*) generated 216 articles for the Senjahopen area and 323 for the Holmbuktura area (Retriever.no, 2017). Our main data are derived from semi-structured and open-ended interviews with local residents, businesses, and public service providers, identified through the media review and by using a snowballing method in which interviewees suggested other relevant names (Blaikie, 2010, p. 179; Easterby-Smith, Thorpe, & Jackson, 2008). The interviews lasted between 30 and 120 min and most were recorded and transcribed. The group interviews were recorded through detailed note-taking.

Interviews were conducted on four occasions during 2015 and 2016. In the Holmbuktura area, 13 people were interviewed in May 2015, immediately after the avalanche season. Interviewees included residents with specific responsibilities, such as school bus- taxi- and snowplough drivers and nursing home managers and five were active in the “Jøvik Development Association”, whose members have publicly voiced concerns about the avalanche situation. Follow-up interviews with three informants were conducted in January 2016 during the avalanche season. We also visited avalanche prone areas to better understand the context (in fact, it was necessary to travel through the avalanche-exposed areas to get to the field sites).

In the Senjahopen area, we conducted, in total, 11 individual semi-structured and open-ended interviews and seven group interviews. Five individual and five group interviews with the local school, retirees, paramedic personnel, local businesses forum and local shop employees were conducted in February 2015, only a few weeks after a three-day road closure. Individuals with personal experience of avalanche and road closure were targeted for interviews. Five individual interviews and two group interviews with retirees and immigrants were conducted in the Senjahopen area in February 2016.

Three background interviews with public organizations (Norwegian Public Roads Administration, Police and The Norwegian Society for Sea Rescue) were conducted in December 2015. These interviews provided a broader understanding of the formal preparedness system.

#### 4. Adaptation strategies

Residents, local businesses and public service providers in the two case areas have developed a number of adaptation strategies to respond to avalanche risk and road closure. Three main categories emerge from the empirical analysis: preparedness, flexible arrangements and influencing decision-makers. The different adaptation strategies evoke, utilize or are shaped by social capital, illustrating how such capital strengthens adaptive capacity. Table 2 summarizes how social capital aspects manifest in the local case study areas.

##### 4.1. Preparedness

The preparedness category encompasses actions anticipating an actual avalanche, risk of avalanche, and/or road closure. Individuals, as well as local businesses, are prepared to minimize discomfort, risk and economic losses in the event of a road closure or avalanche. Social capital manifests in social networks and trust, perception of risk and experiential knowledge. These factors contribute to adaptive capacity.

In the Holmbuktura area, it is common to stock up on food and to carry an extra set of toiletries and clothing in the car, or at the workplace, in case of an avalanche. This is in preparation for if either they or their neighbors are caught on the wrong side of the avalanche, and this action is based on experiential knowledge about what is needed when avalanche and road closures occur.

In addition to packing extra sets of toiletries, arrangements are made to stay with friends, relatives or co-workers if the road is closed. Both Senjahopen and Holmbuktura are described as close-knit and friendly communities, where everyone knows each other and where social networks are imperative for well-being and support. These networks extend beyond the area of residence, exemplified by arrangements made to stay with people in Tromsø if the road is closed and they are unable to return home. Such social networks ensure that people have a place to stay in times of need during

**Table 2. Examples of how social capital manifest in the two case communities**

Social capital aspects	Senjahopen area	Holmbuktura area
Social networks	Reliance on friends and neighbors for assistance and support. By knowing everyone in the community, people also know whom to rely on: "Everybody knows everybody"	Reliance on friends and neighbors for assistance and support
	Facilitate quick dissemination about road closures	Have developed collaborative/private arrangements for spending the night or distribution of food. "You are well received in someone's house if you are unable to go back home" Facilitate quick dissemination about road closures
Trust	Trust in the experts/ people who make decisions about road closures is generally high. Such trust limits economic losses for fish producers. Trust in shared information	Trust in community members and in shared information. But low confidence in current safety measures (road closures)
Place attachment	Appreciation and acceptance of particularly challenging conditions. It is worth the risk to live in this area. Commonly expressed as "We know where we live"	Described as a safe place with fantastic landscapes, and a place that provides a sense of freedom. This makes living there worthwhile
Engaged individuals	Local industries, local politicians and engaged individuals work to alleviate the impacts of road closures. Such individuals are also found in the work place such as in health care, to ensure flexible workhours	Jøvik Development Association and engaged individuals work to alleviate the impacts of road closures. Flexible and creative solutions at the nursing homes ensure that people are safe and taken care of
Local and experiential knowledge	People know exactly when the road will be closed signifying ability to predict, and evaluate the situation. Highly relevant to transportation services. Climate change adds uncertainties to weather predictions	Residents observe the mountainside and monitor weather conditions to evaluate the safety. Relevant for individual residents, services and businesses. Inherently uncertain and unpredictable, but people are used to living with uncertainty
Risk perceptions	"We know where we live" narrative displaying acceptance for road closures, but also seen as problem for certain groups and businesses. Residents avoid travel out of the area during avalanche season, and hesitate in inviting guests and family	Exposure to avalanche risk seen as intolerable by many due the potential for fatal outcomes. Affect social life in that people do not travel and relatives and friends cannot visit But, resilience to infrastructure disruption is emphasized

avalanche season. A nursing home employee states, “When I get stuck out here, I have to find myself somewhere to sleep. It is usually easy.”

A farmer explains that he estimates fodder needs based on weather forecasts and previous experience, and that he always stocks extra fodder in the event of road closure. Despite careful preparations, the consequences of road closure impede the running of the farm. Particularly exposed are the distribution of eggs to market, the sufficient amount of fodder for the animals and the access to veterinary services. One farmer notes,

Road closure is one of the consequences of living out here; it impacts the running of our business. It has clear negative consequences. On several occasions, the eggs have not gotten out of here the week they’re supposed to. So, one thing is that the eggs have to get out, but the most serious consequence is if we get a long closure and we cannot get fodder in here to the hens. It would be a disaster.

Social networks facilitate quick dissemination of necessary information about road closures through the communities. Social media and close contacts with those in charge of snow removal ensure that residents are informed of imminent or actual road closures. If the road is closed for a long period of time, groceries are shipped to the isolated area in Holmbuktura by boat, and people who live there cooperate in delivering the food stuffs to those who need them. The distribution of food is based on voluntary arrangements and goodwill of the social networks. Similarly, in the Senjahopen area preparedness also involves knowing exactly when the road is going to be closed. One interviewee explains,

We have had a trailer fully loaded many times and the guy from the snow removal company calls and says that they have to close the road within an hour. So, normally they let us know before they close the road so we have a chance to get our products out.

The fish producers are given a heads up about road closures, allowing them to deliver the fish in time, thereby reducing economic losses and additional work.

Such strategies are enabled by social networks and through knowledge exchange and are based on trust between the fish producers and the snow removal company. On a few occasions, the snow removers have delayed road closures in order for fish trucks to pass. The option to delay road closure without compromising safety is crucial for local businesses, public services and residents. A health care worker notes, “Usually they don’t close the road until we’ve had a chance to deliver medications and dinners to the nursing home.”

Trust in those who make decisions about road closures is generally high in Senjahopen, and residents highlight the importance of direct communication about imminent road closure with the snow plough driver or the mayor. In addition to well-established social networks, this kind of arrangement requires trust in both the snow plough drivers’ local knowledge and judgement to close the road and in those who express a need to pass through. In contrast, the level of trust is lower in Holmbuktura mainly because avalanches often occur when the road is open, and many of the interviewees expressed low confidence in official decisions to close the road as a protection measure. Perception of risk is, in this case, negatively correlated with level of trust.

A number of negative consequences of living with avalanche risks and road closures emerge from our interviews. The settlements on the outer side of the avalanche become isolated when the sea-shore highway closes in the winter season, as there are no alternative roads. The residents’ ability to participate in social activities during the avalanche season is reduced significantly. According to the interviewees, such limitations affect their quality of life. Although most adult residents can evaluate snow conditions and assess the information on avalanche risk, they cannot always know what the current conditions are and how safe the roads will be. Interviewees emphasize that the roads are

not sufficient for present-day traffic: “We need safe roads. We need the tunnel and avalanche control buildings. The alternative road is not safe, either.”

Risk perceptions play a role in how social life is arranged around the potential for avalanche. During the avalanche season, residents in both case areas avoid making plans involving activities outside the area, such as buying theatre tickets or making dentist appointments in Tromsø. In Senjahopen, grandparents lament that their grandchildren cannot visit them during the avalanche season; the children may not be able to go home in time for school and other activities, and it may not even be safe for them to travel. Residents who live beyond the avalanche sections in Holmbuktura note that they at times prefer that their children stay with friends or relatives on the other side of the section for the road may be open but not considered safe for travel. Others hesitate to invite relatives and especially young children since there is a possibility that they can be caught on one side. A woman living beyond the avalanche area explains, “Social things may sound trivial, but they are important to our quality of life.” Another added, “You miss out on social life during the avalanche season, you stay home rather than being social.”

In contrast with Holmbuktura, some people in Senjahopen are more accepting toward road closures and avalanche risks, as reflected in the statement, “If it is a problem, you cannot live here.” Others might be frustrated over road closure, especially when planning leisure time activities and family visits: “The kids do not come home for Christmas and Easter vacation. I don’t have the opportunity to get away.” Economic losses for local businesses and a reduced social life are some of the consequences of living with avalanche risk.

#### **4.2. Flexible arrangements**

Flexible arrangements pertain to strategies that have been developed to allow everyday life, services and local businesses to function with as few disturbances as possible in the event of an avalanche or road closure. Flexible arrangements are closely related to preparedness and several of these within public services have, to a degree, been formalized. Social capital related to flexible arrangements manifest in place attachment, social networks and trust, perception of risk, and local knowledge.

Strategies entailing a great deal of flexibility have been developed by health care providers in both the Holmbuktura and Senjahopen areas. In Senjahopen, the health service provider has staff living on both sides of the avalanche section. When the road is closed, staff on the inaccessible side carry out the necessary tasks. Sometimes this involves staff having to step in on their day off and typically involves a higher workload for the staff on the “open” side as they have more patients. The nursing home manager notes that this strategy normally works well. In order to plan for health care services during the avalanche season, the care providers are dependent on weather forecasts: “We say that it is alfa omega to be updated on the weather forecast, so we get a hunch on when it will happen. Most of the time, we avoid major surprises.”

If staff cannot get to work due to road closure, they are prepared to take extra shifts later when needed and those already at work have to do overtime. Extra sets of medications are kept on each side of the avalanche area to ensure that health care users are taken care of. However, when the road is closed for extended periods, the manager explains that it can be problematic to obtain the right medications. Interviewees state that a close-knit community where people feel that they can rely on each other in times of need is essential for dealing with avalanche risk. In addition, strong attachment to place is a main motivator to develop strategies and to live with avalanches and infrastructure disruptions: “Avalanche and road closure is an unpractical situation, but we live where we live. Many of us grew up here and are used to such conditions.”

Similar arrangements have developed in the Holmbuktura area, where flexible and creative solutions enable the nursing home in Lakselvbukt to maintain their services during avalanche season. The staff living on the outer side of the avalanche section stay on that side. They always store

medication in the event of road closure or perceived avalanche risk and carefully monitor weather forecasts: “Sometimes we look at the forecast and plan ahead, like taking the medications out there on Friday instead of waiting until Monday.” The most vulnerable health service users living on the outer side of the section are typically moved to the nursing home in Lakselvbukt during winter. This strategy is undertaken in agreement with staff, users and relatives to ensure that they receive necessary medical care during the most unpredictable winter months.

This practice is highly appreciated because it reduces stress and worry about what will happen if the road is closed for an extended period. Thus, social networks and trust play a role in enabling such strategies. In Holmbuktura, many experience anxieties when they, or people they know, have to travel across the avalanche section. At the nursing home, the management takes such concerns seriously and has a policy that allows staff to stay at home and not drive to work if they are scared, i.e. if weather conditions are bad but the road is open. The staff compensate by working extra hours and shifts on other occasions. In contrast, if the road is closed, the staff's salary is unaffected due to a compensatory scheme the nursing home has with the Norwegian Labor and Welfare Administration. This is an example of how risk perception plays a role in developing strategies and arrangements that have been formalized over time. A recent event noted by residents illustrates how dire the conditions can be: A resident living on the outer side of Holmbuktura had a stroke during a road closure, and according to the interviewees, it took eight hours before the person received medical help because of the difficulties in accessing the site by both road and helicopter.

Social networks and trust are also essential in the school arrangements and strategies. The primary school in Lakselvbukt enrolls children who live on the outer side of Holmbuktura. The uncertainty involved in sending children between school and home has resulted in special arrangements. To decrease the risk and discomfort parents feel in case of a road closure or elevated risk of avalanche, the pupils may stay in the headmaster's house or in privately arranged housing. The pupils have a double set of schoolbooks and can study from home with electronic teacher supervision. The contingency plan includes close contact between the parents and teachers in case of potential road closure or avalanche risk. The plan stipulates that the decision to send the children to school resides with the parents rather than with the school. The headmaster emphasizes that it is very important to her that the parents take the necessary precautions themselves in the event of bad weather, e.g. by keeping their children at home. Informants recalled occasions when their children were caught at school due to road closure or avalanche risk: “We were prepared that it could happen, so we had an arrangement with someone in case it did happen...if there was an avalanche, they could stay there.” As in other examples from Holmbuktura, risk perception and the experience people have in crossing the avalanche section, which poses real potential for fatalities, have shaped how the community deals with risk. In addition, trust and engagement from the headmasters to the parents appear as essential to these kinds of arrangements that now are formalized in the school's contingency plan.

The school in Senjahopen also enrolls students that live in Skaland, outside the avalanche section. Similar to Holmbuktura, the children can be homeschooled by using an internet-based education program in the event of a road closure. The school has, moreover, developed an emergency guidebook that includes avalanches, and pupils are taught how to act in rough weather and during avalanche events. Schoolteachers also evaluate weather conditions before going on school trips. Many residents express the importance of ensuring that newcomers such as refugees and seasonal laborers acquire such local knowledge.

#### **4.3. Influencing decision-makers**

While dealing with road closures in everyday life, residents in both Holmbuktura and Senjahopen seek to influence decision-makers to implement measures such as tunnels to prevent avalanche risk and road closure. Social capital manifests in engaged individuals.

The high quality of life many see as intimately tied to Holmbuktura spurs residents to engage in solutions that would reduce avalanche risk. While risk perceptions are not uniform across the area,

many associate driving through the avalanche section with stress and worry. Some also hold that road closures and risks hinder development in the area and make it less attractive for young families. Consequently, the population is declining as well as aging. Many interviewees emphasize that Holmbuktura is in need of an influx of young people. A couple in their early 60s notes, “We are the last ones that built a house on this side in 1983. Those who live out here is our age. It is a sad trend.” Although they attribute the decline in younger families to a general trend of urbanization, avalanche risk also plays a role as they claim that there is more development in Lakselvbukt than on the outer side of Holmbuktura:

You cannot be certain about getting back home again or the other way around. And it is not possible to work from home in all occupations. This may be one reason to why people do not want to live here.

Many residents in the Holmbuktura area are actively trying to find solutions to the problems that arise with avalanche risk, road closures and isolation. For example, the “Jøvik Development Association” works for the development of the outer side of Holmbuktura and the settlements Olderbakken and Jøvik (Utviklingslag, 2016). In addition to activities such as beach clean ups, maintenance of community buildings and roads, the development association has an avalanche group that works to secure the road. One engaged individual in Holmbuktura has mapped the locations, extent and timing of avalanches within the section. He has found that avalanches are particularly frequent within a certain area of the section and he expresses a hope that the Road Administration will at least build a tunnel in this particular area. The avalanche group has written several opinion pieces in local and regional newspapers calling for securing the road (Heitmann, 2017). The group continues to influence politicians. One person notes, “We have tried to influence politicians and those involved with transport in the County, but we’re not getting anywhere,” Efforts to influence decision-making have been ongoing for several years and several informants expressed frustration that so little has been done to secure the area.

In Senjahopen, the fisheries sector (highly dependent on reliable infrastructure) is actively trying to influence politicians to improve the road conditions. The projected growth in the fisheries sector serves as an incentive to develop and upgrade infrastructure and transportation. Local politicians lobbying for improved infrastructure do so because the current situation impedes the local economy: “Good roads for industry are also important for municipality development.” Another concern expressed by local politicians is that road closure may reduce the attractiveness of the area, especially for people who are not used to such conditions, such as work immigrants and refugees.

The combination of high perception of risk and strong place attachment makes it meaningful to try to influence decision-makers in order to secure a better quality of life. It requires engaged individuals, and local and experiential knowledge to devise strategies that might convince politicians to address the problem.

## 5. Concluding discussion

The interplay and dynamics of adaptive capacity and social capital are illustrated in this paper through empirical findings of locally developed adaptation strategies. In this study, we have expanded the concept of social capital, as it is typically discussed in the literature, to include empirically derived categories that are often connected to adaptation research (e.g. perceptions of risk and engaged individuals). We argue that social networks and trust, place attachment, local and experiential knowledge, engaged individuals and perception of risk are all significant aspects of social capital that, together, play a significant role in activating adaptive capacity, which in turn results in adaptation strategies. We have shown that the adaptation strategies used to alleviate avalanche risk and road closures in our two case areas are the outcome of the interaction between the social capital variables. Both case areas have developed similar adaptation strategies which we have organized into three broad categories: preparedness, flexible arrangements and influencing decision-makers.

In preparing for an avalanche or road closure, social networks and trust, perception of risk and experiential knowledge are important aspects of social capital that shape actions and strategies. In both Senjahopen and Holmbuktura, social networks enable responses to infrastructure disturbances and avalanche risk. In contrast to many other hazards, road closures and avalanche events are regular occurrences. Both the option of staying at someone's house and securing a guarantee that your children will be looked after in the event of a road closure require and generate social capital. We suggest that such local and flexible arrangements enable repeated interaction that can provide and amplify trust and cooperation between people, which in turn are prerequisites for collective action (Akama et al., 2014).

The networks observed in Holmbuktura and Senjahopen can be characterized as bridging capital (Woolcock, 2001). Bridging capital refers to relations of people with different backgrounds but a common interest, such as neighbors, colleagues or people who live in the same community. Bridging networks are often contrasted with bonding networks, meaning relationships between people of the same background, family or faith and linking networks, referring to relationships between locally based groups and external organizations (Woolcock, 2001). Harrison, Montgomery, and Bliss (2016) found in their study of adaptive capacity and social capital in U.S. mining communities that adaptation was directly linked to bridging networks. Adaptation actions carried out in social networks are motivated by a strong sense of place that we found to be present in both case sites. Findings from Senja, adjacent to our case areas, show that people are motivated to act and adapt based on their emotional attachment to place, expressed through a strong willingness to continue living in the communities, which in turn motivates adaptation to both negative socio-economic trends and climate change (Amundsen, 2013).

The local collective solutions that have emerged, such as managing health services and schooling, have to some extent been formalized, which supports research claims that local actors need to be active in order to gain support from the state (Agrawal & Perrin, 2009).

Perception of risk differs between the case areas and has influenced adaptation strategies in combination with social networks and trust, local knowledge and engaged actors. Both the school and nursing home in the Holmbuktura area have developed arrangements that allow parents and staff to make their own decisions about whether it is safe to cross the avalanche area when the road is open. In both areas, trust in the judgement of those who close the road and predict avalanches emerge as critical (e.g. Jaedicke et al., 2008). In addition, the actual risk of a fatal outcome is higher in Holmbuktura than in Senjahopen (Jacobsen et al., 2016), which helps to explain why risk perception is higher among residents there.

When distilling the risk of avalanche, associated consequences, adaptation strategies and evoked aspects of social capital, three significant implications emerge, which warrant further discussion and research. The first pertains to the high adaptive capacity these communities employ to deal with risk, and to the fact that different aspects of social capital play a role in ensuring and shaping such capacity. People in the case areas living with avalanche risk have the adaptive capacity to develop strategies such as flexibility and preparedness and trying to influence policy makers to reduce the risks. We found that local residents are resourceful and know how to mobilize social networks. People are willing to live with risk because of their place attachment and their trust in local expert judgement about road closures. Other strategies, such as influencing decision makers are possible because of engaged individuals. While the adaptation strategies that handle avalanche risk and road closure are well-developed, the flip-side is that these same strategies may inadvertently deplete critical social capital and adaptive capacity sources.

This brings us to a second implication: adaptation strategies come at a cost. In both case areas, local strategies and arrangements have developed to allow everyday life, services and local businesses to function with as few disturbances as possible when an avalanche occurs or when the road is closed. Such adaptive strategies can be related to what Pelling (2010) denotes, "adaptation as

resilience”, which merely maintains rather than improves or transforms societal functions. Our findings demonstrate that there are limits to local adaptation strategies, and that there are negative societal consequences associated with avalanche risk and road closure. Further, there are significant costs associated with sustaining functions of everyday life and critical services. In both case studies, such costs are relatively similar and include limited mobility and participation in social activities, economic losses for businesses and the potential for failure in delivering health services, but they manifest in different degrees in the two communities.

Informants in Holmbuktura also expressed fear that the cost of living with avalanche risk reduces community attractiveness, especially to young families. Residents in Senjahopen and Holmbuktura have engaged in action to influence decision-makers in order to implement measures that make the areas and roads safer, which clearly indicates that their seemingly high adaptive capacity does not mean that they are content with their situation. Here, social capital manifests through engaged individuals and social networks between the communities and politicians and decision-makers in outside the areas. These networks can be characterized as linking networks (Woolcock, 2001). However, the strengths of these networks are questionable, as no alternative measures that the residents have asked for have yet been implemented. As highlighted by Harrison et al. (2016), strong bridging networks within a community and linking social networks that connect the community with external actors are often necessary to achieve more substantial adaptation measures.

The final implication pertains to the local context in which adaptation takes place. While the interaction of social capital and locally developed adaptation strategies to deal with avalanche are quite similar in the two studied areas, which is not surprising given the similar topography and societal conditions, there are significant differences in the broader socio-economic development trends. In the Holmbuktura area, the trend is defined by decreasing job opportunities and reduced population, while in Senjahopen this is reversed with more jobs, prosperity and influx of new residents. This weakens the adaptive capacity in Holmbuktura and strengthens it in Senjahopen. The question remains whether these progressions will lead to the development of new forms of social capital in both areas. We suggest that, although interaction of social capital aspects and adaptive strategies manifest in both locations and enable day-to-day responses to avalanche risk, the broader socio-economic context and its influence on adaptive capacity will determine long-term adaptation and community viability. This study illustrates that attention to the local context is critical for understanding both the impacts of natural hazards such as avalanche, and the socio-political contexts that may enable or hinder activation of adaptive capacity, social capital and adaptation strategies.

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#### Author details

Grete K. Hovelsrud<sup>1,2</sup>  
E-mail: [grete.hovelsrud@nord.no](mailto:grete.hovelsrud@nord.no)  
ORCID ID: <http://orcid.org/0000-0001-6549-8194>  
Marianne Karlsson<sup>1</sup>  
E-mail: [mka@nforsk.no](mailto:mka@nforsk.no)  
Julia Olsen<sup>1</sup>  
E-mail: [jol@nforsk.no](mailto:jol@nforsk.no)

<sup>1</sup> Nordland Research Institute, Bodø, Norway.

<sup>2</sup> Faculty of Social Sciences, Nord University, Bodø, Norway.

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